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NUCLEAR REGULATORY COMMISSION
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MEMORANDUM FOR: B. C. Rusche, Director
Office of Nuclear Reactor Regulation

R. B. Minogue, Director
Office of Standards Development

FROM: S. Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER-8, DECAY HEAT DATA APPLICABLE TO LOCA EVALUATION

This memorandum transmits the results of completed research which is applicable to ECCS performance calculations for light water reactors fueled with U-235. The attached reports (Appendices 1-3) are in draft form and are undergoing a broad technical review (Appendix 4). The latter is expected to be completed in May, with final reports available in June. Furthermore, a revised ANS-5.1 standard based primarily on this work is expected to be publicly available at the same time.

1. At Oregon State University (OSU), Prof. B. I. Spinrad has employed the most recent Evaluated Nuclear Data File (ENDF) to calculate a decay heat curve by summing decay energies in the proper proportion dictated by yields and half-lives.* OSU has also evaluated the uncertainty in the decay heat curve arising from the accumulated uncertainties in the nuclear data. The summations are shown in Figures 1 and 2. They are compared to ANS-5.1, and to the 10 CFR 50 Appendix K licensing value (ANS-5.1+20%). The 20% addition to the ANS-5.1 reflects an engineering judgment of the uncertainty associated with the data used to develop the ANS-5.1 standard and has no statistical basis. The uncertainty in the OSU curve, however, has been evaluated statistically, so that confidence limits may be assigned. For example, Figures 1 and 2 also include a curve which is 1.65 standard deviations above the OSU best estimate curve. For a normal distribution of errors, this represents a 95% probability that the calculated value falls below the upper bound curve. Appendix 1 provides a detailed description of how the OSU curve was derived.

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*Note: ENDF is an evaluated data file which contains experimental yields, decay energies, and half-lives for fission products and also includes estimates of comparable unmeasured data based upon the best available semi-empirical nuclear data models.

2. The validity of the summation calculations has been verified by three recent experiments to measure the fission product decay heat of U-235 irradiated in a thermal flux. The experimental techniques are reviewed in Appendix 1. An experiment at IRT Corporation was funded by the Electric Power Research Institute (EPRI) and employed nuclear spectroscopic techniques. The NRC-sponsored program at ORNL (see Appendix 2) used beta- and gamma-ray spectroscopy, and the NRC-sponsored program at LASL (see Appendix 3) employed calorimetry. In Figure 3 the data from all three experiments are plotted in a consistent manner* and are compared to the OSU summation calculation and ANS-5.1. As seen from Figure 3, the agreement between the measurements and the summation calculation is excellent and demonstrates that the 1971 ANS-5.1 decay heat standard, even without adding 20%, is conservative for the first 2000 seconds.

3. During the Fourth NRC Water Reactor Safety Research Information Meeting Prof. Spinrad presented calculations (Figure 4) demonstrating that PuO_2 decay heat is, at most, 90% of the value of UO_2 decay heat during the time frame of interest for a LOCA. Thus, the UO_2 curve represents an upper bound of the decay heat in commercial fuel rods throughout life, and would also conservatively bound the decay heat of Pu recycle fuel. ORNL and LASL are currently measuring the decay heat of Pu-239 irradiated in a thermal neutron flux to validate this finding.

Evaluation and Applicability

1. These programs and their results have been reviewed repeatedly while in progress by the NRC Decay Heat Review Group and by the ANS-5.1 Working Group. The consensus is that the work has been conducted competently and with sufficient attention to technical detail. A revised ANS-5.1 standard, based primarily on this new information has been proposed. The ANS-5.1 Working Group has presented the revised standard to the ANS-5 committee with the expectation that it will be publicly available by June, 1977.

   RES has instituted through the Nuclear Safety Information Center an independent review of the NRC-sponsored program (Appendix 4). It is expected that scrutiny by experts and subsequent presentation to the scientific community at large will assure that all significant technical points have been identified and adequately addressed.

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*Note: In order to put all of the experiments on the same basis it is necessary to adjust them for the fact that the irradiations consisted of finite time intervals ranging from 2 seconds to 24 hours and did not continue to infinity, as is normally done when presenting decay power. The adjustment is made by adding the heat expected from the end of testing to infinity using the summation calculations.

2. The RES staff has used FRAP-T (our "best-estimate" fuel behavior code) to perform sensitivity calculations to determine the impact of these new results on peak clad temperature during a PWR LOCA. The maximum reduction in peak clad temperature during a double-ended cold leg break between using ANS-5.1 and 10 CFR 50 Appendix K (ANS-5.1+20%) decay heat values could approach 190°F. The maximum difference between using 10 CFR 50 Appendix K decay heat values and the best estimate OSU decay heat curve could be higher than 300°F. These figures are presented only as an example. The differences predicted in peak clad temperature depend, of course, on the design of the fuel and of the ECCS.

3. The calculational techniques employed by Spinrad realistically consider all significant phenomena relevant to estimating decay from thermal fission of U-235. This is born out by the excellent agreement between predicted and experimentally observed values. However, the application of the results of such calculations to prototypical LWR conditions may introduce small deviations in the conservative and nonconservative directions. For example, assuming that all fission products derive from U-235 (i.e., ignoring depletion and conversion to Pu-239) would lead to increased overestimation of decay heat as burnup increases. In another example of conservatism, the contribution to decay heat from activation and decay of fission products which capture neutrons depends upon the exposure and flux level of the fuel. In the calculations these parameters are chosen and held constant such as to maximize this contribution, which is generally less than one percent over the first 1000 seconds after shutdown.

   One potential nonconservatism is the neglect of decay heat from fast fission of U-238 in the calculations to date. Though this is calculable, it would not be significant because of the relatively small number of fast fissions in an LWR core. The revised ANS-5.1 will account for Pu-239 (thermal) and U-238 (fast) fissions.

4. These results confirm that there is a large degree of conservatism being used in the evaluation of ECCS capabilities by the Regulatory Staff. Planning for a change in evaluation procedures could be started now, anticipating the availability of final reports and the revised ANS-5.1 standard by June of this year.

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RES will be happy to furnish you any cooperation and assistance that you may require.

Saul Levine
Saul Levine, Director
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Enclosures:
Appendix 1: B. I. Spinrad, Evaluation of Fission Product After-Heat, Annual Report, July 1, 1975-September 30, 1976. NUREG-0018-4, Oregon State University, January, 1977.
Appendix 2: J. K. Dickens, T. A. Love, J. W. McConnell and R. W. Peelle, Decay Heat of 235-U Fission Products by Beta- and Gamma-Ray Spectrometry, presented at the Fourth NRC Water Reactor Safety Research Information Meeting, Gaithersburg, Maryland, September, 1976.
Appendix 3: J. L. Yarnell and P. J. Bendt, Decay Heat by Calorimetry, presented at the Fourth NRC Water Reactor Safety Research Information Meeting, Gaithersburg, Maryland, September, 1976
Appendix 4: Letter, L. S. Tong, to W. B. Cottrell, Technical Review of Decay Heat Studies, December 23, 1976.

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